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THE INFLUENCE OF BODY CHARACTERISTICS ON HUMAN TEMPERATURE RESPONSES TO HIGH ALTITUDE COLD

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ABSTRACT

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In order to determine the possible role of body characteristics in mens ability to adapt and acclimatize to high altitude cold the physical characteristics of four groups of individuals were correlated to their body temperature responses when exposed to an ambient temperature of 14° C. for two hours at an altitude of 3760 meters. The body characteristics chosen for analysis were, age, standing height, sitting height, weight, % body fat, fat free weight and sum of skinfold. The four groups were U.S. Whites, University of Cuzco White and Indian sutdents and native Indian villagers.

The results showed significant association between body characteristics and body temperatures in all groups. Fat acted as insulation in all groups and fat free weight had very significant positive effects on total body heat content. The total body heat content of native Indian villagers was more significantly affected by age than in other groups and fat-free weight in this group had a strong effect on peripheral body temperatures. The result agree with the suggestion made in the previous progress report that native Indian villagers have a higher metabolic response to cold stress.

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1. Introduction

Studies over the past ten years have shown that when individuals are exposed to moderate total body cooling, much of the individual variability in response may be based on individual variation in body structure and composition (Buskirk et al. 1963). Since population isolates of man are often dramatically different in body size and composition, many of the differences that have been reported for population isolates may be accounted for by these differences in body structure (Buskirk et al.,1963, Baker and others, 1963a). Despite the fact that body structure has a significant effect on temperature responses during body cooling it cannot be assumed that it has a similar effect on all groups. In a study of American Negroes and Whites it was found that body fat seemed to provide less insulation for American Negroes than it did for U.S. Whites (Baker, 1959). Theoretically other body characteristics such as age, surface area, and the mass of active tissue should also effect temperature responses during body cooling. However studies of these problems have so far produced meager results (Baker, 1960, Bernstein et al., 1956).

2. Methods

Sample. In the present report, the data from the four groups of men used for studying adaptation to high altitude cold in the Andes have been analyzed to determine for each group the relationship between body characteristics and temperature responses during two hours of cooling at 14°C. A complete description of the four samples is given in the Annual Progress Report, dated July 1, 1963 (Baker, 1963). Briefly, these samples consisted

of 24 native Highland Peruvian Indians living in traditional manner, 12 University of Cuzco students of Indian derivation, 12 University of Cuzco students of White derivation, and 5 U.S. Whites who had spent three to six months in the highlands of Peru. Table 1 gives the physical characteristics of the four populations.

TABLE 1

Mean and Standard Deviation of Body Characteristics for Total Body Cooling Studies

Body Charact.	U.S. Whites		Cuzco Whites		Cuzco Indians		Chinchero Indians	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Age	27.2	5.0	20.4	2.2	20.3	2.4	35.0	18.0
St. H.	1762.0	26.1	1677.1	44.5	1671.0	55.6	1545.9	45.8
Si. H.	931.2	13.0	892.0	24.9	881.5	26.7	827.4	32.8
B.W.	69.3	5.9	60.9	5.9	60.9	5.8	55.1	5.1
% B.F.	10.5	2.0	8.6	1.4	9.0	1.8	7.9	1.1
F.F.W.	62.0	4.2	55.6	[illegible].1	55.4	4.8	50.7	4.7
S. Sf.	53.6	13.7	41.5	12 2	44.3	16.4	32.9	9.9

Legend

St. H. = Standing height (mm.)

Si. H. = Sitting height (mm.)

B.W. = Weight (kg.)

% B.F. = Percent Fat

F.F.W. = Fat Free Weight

S. Sf. = Sum of Skinfolds

The two University of Cuzco populations were carefully matched by selection for body characteristics and as a consequence there are no

significant differences in the means of the measurements of the two populations. However, standard deviations vary slightly particularly that of standing height. The Chinchero Indian population and the U.S. White population are different from each other and from the two student populations in most characteristics. While none of these populations is large enough to be considered representative of their respective larger population groups, the differences between them reflect the directions of the difference between the populations. Thus, the native Indian population is the shortest of the groups and the lightest in body weight; it is also the lowest in body fat. The U.S. White population is substantially taller, heavier and fatter than the Cuzco student population. Despite the very small size of the U.S. White sample they are quite close to estimates of body size and composition obtained on a U.S. White population of comparable age (Brozek & Henschel, 1961).

Testing Conditions. All groups were exposed nude while lying on canvas cots for two hours in an ambient temperature of approximately 14°C. Exact details of temperature conditions are presented in the previous report of July 1, 1963. However, it should be reiterated that conditions in the dressing room prior to the actual cooling exposure were not constant and produced significant cold stress so that thermal equilibrium cannot be assumed in these groups at the beginning of the study.

Of the body temperature measurements collected during the cold exposure, four measurements were selected for analysis in relation to body structure. These were: (1) rectal temperature, (2) mean weighted skin temperature, (3) hand temperature, and (4) toe temperature. Rectal and mean weighted skin temperature have been included because they represent the best two measures of the overall thermal characteristics of the individual. Hand

and toe temperature were included because in group comparisons, higher intergroup variability was encountered. They are also indicators of peripheral heat flow. In the analysis, physical characteristics have not been combined into indices, such as surface area, because such combinations are statistically less valid characterizations of the body than the raw measurements. No attempt was made to integrate rectal and skin temperatures into estimates of thermal insulation and/or total body heat content using published formulas because it is felt that individual structural differences are significant in true insulation and total body heat content. The calculation of such values by formulas derived from U.S. White groups would therefore confuse the interpretation of the results (Buskirk et al., 1963, Baker, 1958).

3. Results

In the previous analysis for group differences it was found that the two University populations did not significantly differ from each other in any of the temperature measurements used for this analysis. The White and Chinchero Indian groups did differ from each other and from the University populations. Despite the lack of significant differences between the two University groups they have not been combined for this analysis since the similarity in average response does not necessarily signify a similarity in the role of body structure characteristics in cooling responses. For example, in the previously cited study of Negro-White differences in response to moderate total body cooling, the two groups did not significantly differ from each other in average response. Nevertheless,

in that study the analysis of structure in relation to temperature indicated a significant difference in the insulation provided by body fat in the two groups.

The relationship between the physical characteristics and the temperature responses in the four groups was measured by the Pearson product-moment r. The correlation coefficients for each of the time intervals at which temperature measurements were made is shown in Appendix A. High order correlations were found between physical characteristics and rectal and mean weighted skin temperatures in the U.S. White groups. However, the very small size of this sample prevented the majority of these correlations from being statistically significant. If the correlation patterns for all time intervals are considered, significant correlations exist between fat and mean weighted skin temperature with nearly comparable correlations between fat and rectal temperature. The relationship between fat-free weight and rectal temperature is also high throughout the test period. At the end of two hours this relationship provides the most highly significant correlations. The correlations found in the White group agree with the results of other studies in that they show body fat to be negatively correlated with skin temperature while it is positively correlated with rectal temperature. At the beginning of the cooling period, standing height and sitting height were highly correlated to toe and hand temperature in a negative direction. However, the correlations fall considerably below significant levels at succeeding time intervals.

For the two University student populations, correlations are generally of a much lower order than was found for U.S. Whites. Although there appear to be some consistent patterns, such as a positive relationship between fat and rectal temperature and a negative relationship between fat and mean weighted

skin temperature, there are no significant _r's_. More significant correlations emerge from the relationship between body structure, and toe and hand temperature. The two groups do not appear to be similar in this regard. By the end of the cooling period, the Cuzco Whites show consistently significant association between measures of fat-free weight and body fat with toe temperature. The Cuzco Indian group, however, fails to show any positive association and instead shows at the very end of the cooling period a highly significant correlation between age and toe temperature. Hand temperature _r's_ are lower, although in the Cuzco White sample there is consistent and significant association between the measures of body fat and hand temperature. Again these are positive associations indicating the higher the body fat, the higher the hand temperature. These patterns do not emerge in the Cuzco Indian group.

Because of the larger sample size, the Chinchero group is the most suitable of the four groups for correlation and regression analysis. Thus, although correlations are substantially lower than they are in the U.S. White groups, there are more statistically significant correlation coefficients. In contrast to the U.S. White group, body composition has a low order of correlation with rectal and mean weighted skin temperature. The only significant pattern seems to be a positive association between the sum of skinfolds and the rectal temperature. In that this is a positive association, the results conform to findings on U.S. Whites. On the other hand, a highly significant negative relationship between age and both rectal and mean weighted skin temperature develops over the two hours of cooling. No such association with age is found in the U.S. White group.

In summary, the single correlations suggest that the U.S. Whites respond to high altitude cooling with the same relationship between body structure and temperature as has been found by other investigators in controlled laboratory experiments at low altitudes. The two University populations do not seem to be identical to each other in the relationship of body structure to temperature responses, nor do they appear to be identical to either of the other two groups. The Chinchero Indian group shows a substantially different pattern, with age the dominant factor and body composition apparently of less significance to overall body cooling. However, the groups are not comparable to each other in body structure except for the two University populations and the analysis of simple correlations does not necessarily show the accurate pattern since the measures of body structure are interrelated. Therefore, an analysis based on multiple correlation with parsimony was undertaken.

The multiple correlation with parsimony technique is simply a standard multiple correlation with a subsequent series of single variable eliminations from consideration of many independent variables to a final indication of the prime predicting variable. By this method it is possible to determine which of the body structure factors is most significant in relation to an individual body temperature. Multiple correlation with parsimony was used to relate the physical characteristics of each group to each of the temperature measurements. Table 2 summarizes the results of this analysis for time interval 120, i.e. the last measurement of temperatures during the study.

Tabl 2

Multiple correlation with parsimony analysis of body characteristics in relation to body temperatures after 120 minutes of cooling at 14° C.

U.S. Whites N=5

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
All characteristics in Table 1	R= .99	R=.99	R=.99	R=.99
Most significant Variables	Age,St.H. & S.Sf.	FFW & S.Sf.	Age&FFW	St.H., FFW, S. Sf.
	R=.89	R=.95	R=.98	R=.98
Prime predictor	S.Sf. r=.45	FFW. r=.50	FFW. r=.92	S.Sf. r=.-83

Cuzco White N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
All characteristics Table 1	R=.89	R=.54	R=.70	R=.61
Most significant variables	St.H & Wt.	---	St.H., Wt.& S.Sf.	St.H ., Wt.S.Sf.
	R=.86		R=.65	R=.48
Prime predictor	Wt. r=.69	S.Sf. r=.47	S.Sf. r=.55	St.H. r=-.40

Cuzco Indians N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
All characteristics in Table 1	R=.80	R=.68	R=.70	R=.87
Most significant	---	St.H.&FFW	St.H.&FFW	Age, Si.H., %F, FFW
		R=.59	R=.65	R=.86
Prime predictor	Age r=.79	St.H. r=.34	St.H. r=-.23	Si.H.r =-.54

Chinchero Indians N=24

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
All characteristics in Table 1	R=.79	R=.56	R=.74	R=.50
Most significant variables	Age,Wt.,%Fat	Wt.,%Fat,S.Sf.	Age,Si.H.& S.Sf.	Age,Si.H.
	R=.63	R=.51	R=.73	R=.47
Prime predictor	Wt. r=.48	Wt. r=.35	Age r=-.61	Age r=-.41

Legend St.H. = Standing height (mm), Si.H. - Sitting height (mm), B.W. = Weight(kg.)
% B.F. = Percent Fat, F.F.W. - Fat Free Weight, S.Sf. = Sum of Skinfolds.

The notation of "all characteristics" refers to all the body characteristics shown in Appendix A. The selection of the second item labled "most significant variables" is based on a somewhat subjective criterion. The small sample sizes made impossible the selection of the border line between significant drops in R values by rigorous statistical tests. Therefore, the judgments were arbitrarily made by inspection. The very high R values shown for the U. S. White sample should probably not be accepted as proof of perfect association. An increase in the number of variables automatically adjusts multiple correlation Rs to a higher value and when as many characteristics as were used in this study are submitted to multiple correlation, R values will reach a very high value in small samples. Nevertheless, the results do suggest a very high degree of association between physical characteristics and body temperature responses in the U.S. Whites.

Correlations of body characteristics to temperature in the other three groups are of a lower order. However, substantially R values are obtained in most cases and the consideration more than one characteristic at a time improves prediction considerably in most instances. Considering the small sample size involved in each of the groups with the exception of Chinchero, the major value of the multiple correlation with parsimony probably lies not in the derived R values but in the indication of which body characteristics are the prime predictors of the body temperatures. Table 3 summerizes for each of the body temperature measurements the prime predicting body characteristic and the next most important contributing characteristic.

Table 3

Body characteristic predictors as determined by multiple correlation with parsimony

Exposure to 14°C. in minutes	0		20		40		60		80		100		120	
Group	Prime Pred.	Contrib Pred.	Prime Pred.	Contrib Pred.	Prime Pred.	Contrib Pred.	Prime Pred.	Contrib Pred.	Prime Pred.	Contrib Pred.	Prime Pred.	Contrib Pred.	Prime Pred.	Contrib Pred.
Hand Temperature														
U. S. Whites	FFW	SSF	St.H	FFW	FFW	SSF	FFW	St.H	FFW	SSF	FFW	SSF	FFW	SSF
Cuzco Whites	A	St.H	SSF	St.H	BW	SSF	SSF	St.H	SSF	Si.H	Si.H	SCF	SSF	Si.H
Cuzco Indians	Si.H	A	Si.H	FFW	Si.H	FFW	Si.H	FFW	Si.H	St.H	Si.H	FFW	St.H	FFW
Chinchero Indians	Si.H	%BF	BW	%BF	Si.H	%BF	Si.H	St.H	Si.H	%BF	BW	A	BW	%BF
Toe Temperature														
U.S. Whites	St.H	SSF	A	FFW	St.H	FFW	FFW	SSF	FFW	SSF	FFW	SSF	SSF	A
Cuzco Whites	BW	St.H	BW	A	BW	St.H	BW	St.H	BW	St.H	BW	St.H	BW	St.H
Cuzco Indians	A	St.H	A	%BF	St.H	A	A	%BF	A	%BF	A	Si.H	A	%BF
Chinchero Indians	BW	SSF	BW	SSF	BW	%BF	BW	SSF	BW	%BF	BW	%BF	BW	%BF
Rectal Temperature														
U. S. Whites	A	FFW	A	FFW	A	FFW	FFW	A	FFW	A	FFW	A	FFW	A
Cuzco Whites	BW	%BF	BW	SSF	SSF	BW	SSF	BW	SSF	BW	SSF	BW	SSF	BW
Cuzco Indians	A	FFW	A	FFW	A	Si.H	FFW	St.H	FFW	St.H	FFW	St.H	St.H	FFW
Chinchero Indians	A	%BF	A	%BF	A	SSF	A	SSF	A	St.H	A	St.H	A	St.H
Mean Weighted Skin Temperature														
U.S. Whites	SSF	St.H	SSF	A	SSF	FFW	SSF	FFW	SSF	FFW	SSF	FFW	SSF	St.H
Cuzco Whites	St.H	SSF	St.H	BW	St.H	A.	St.H	A.	St.H	BW	St.H	A	St.H	BW
Cuzco Indians	Si.H	FFW	Si.H	FFW	Si.H	%BF	Si.H	%BF	Si.H	FFW	Si.H	%BF	Si.H	%BF
Chinchero Indians	BW	A	A	Si.H	A	SSF	A	SSF	A	SSF	A	SSF	A	St.H

A=Age, St.H = Standing Height, Si.H = Sitting Height, BW = Weight, % BF = Percent Fat, FFW= Fat Free Weight, SSF = Sum of Skinfolds

Even when considering single prime predictors the limitations imposed by the small sample size should not be neglected. Therefore, only the consistent and over-all trends should probably be considered and minor shifts of prime predictors from one time period to another may be considered statistical artifacts. The results of this analysis indicate some variation from the conclusions which were derived on the basis of simple correlations. In some instances the findings from the simple correlations were reinforced. For example, in the U. S. White sample fat-free weight and skin folds remain highly significant in relation to mean weighted skin and rectal temperature. The two University student populations do not show consistent differences in the prime contributors when body characteristics are related to rectal or mean weighted skin temperature by this method. However some differences between the student groups remain. Age appears to be the prime predictor for toe temperature in the Indian students while body weight is more significant in the White group. Whether there is a significance to this difference or whether it is simply the product of random variation cannot be determined until larger groups from the same populations are studied. Within the Chinchero Indian group multiple correlation again shows age to be a prime factor in the measure of total body heat. Of secondary importance to mean weighted skin temperature and rectal temperature are measures of body fat. On the other hand, toe and hand temperatures do not seem to be as significantly affected by age and measures of fatness. Instead, total body size is of greater significance to these body temperatures.

<u>Regression Analysis</u> Although the U.S. White sample is small, the high correlations and conformance of findings to previous studies

of the relationship of body fat to body temperatures during cooling, make the further analysis of the relationship of body structure to temperatures useful. Regressions of body fat and fat-free weight to rectal temperature and mean weighted skin temperature are shown in Table 4.

Table 4

Regressions for predicting rectal and mean weighted skin temperatures from percent of fat in the body and fat-free weight.

U. S. Whites

Rectal temperature

Time	% Body Fat regression	F.F.W. regression in Kgs.
0	Rectal Temp. = .215x + 97.21	Rectal Temp. = .105x + 92.95
20	Rectal Temp. = .233x + 96.78	Rectal Temp. = .121x + 91.72
40	Rectal Temp. = .218x + 96.88	Rectal Temp. = .107x + 92.53
60	Rectal Temp. = .230x + 96.61	Rectal Temp. = .120x + 91.69
80	Rectal Temp. = .230x + 96.51	Rectal Temp. = .116x + 91.74
100	Rectal Temp. = .276x + 9[illegible].93	Rectal Temp. = .151x + 89.46
120	Rectal Temp. = .257x + 96.17	Rectal Temp. = .137x + 90.90

Mean Weighted Skin Temperature

Time	% Body Fat regression	F.F.W. regression in Kgs.
0	M.W.S.T. = -.385x + 86.64	M.W.S.T. = -.115x + 89.73
20	M.W.S.T. = -.510x + 87.50	M.W.S.T. = -.121x + 89.66
40	M.W.S.T. = -.531x + 87.20	M.W.S.T. = -.106x + 88.41
60	M.W.S.T. = -.480x + 86.57	M.W.S.T. = -.107x + 88.17
80	M.W.S.T. = -.579x + 87.72	M.W.S.T. = -.115x + 88.99
100	M.W.S.T. = -.526x + 87.45	M.W.S.T. = -.108x + 88.63
120	M.W.S.T. = -.433x + 86.38	M.W.S.T. = -.110x + 88.66

Both fat-free weight and body fat show positive slope association with rectal temperature. These slopes are fairly steep indicating a strong effect of these variables upon rectal temperature. Over the cooling period, from the initial reading to the final reading, there is an increase in the steepness of the slope. This is not consistent from one time period to the other but it appears that over the total time

period there has been an increase in slope. This would suggest that both fat-free weight and body fat increase in their significance in association to rectal temperature as the body is further cooled by cold exposure. The regressions between body fat and fat-free weight with mean weighted skin temperature show the opposite slope, that is, the higher the body fat and the higher the fat-free weight, the lower the skin temperature. This agrees with previous findings that fat acts as insulation. The negative relationship between fat-free weight and skin temperature may be a valid finding or may simply be a product of the high correlation between body fat and fat-free weight in this small sample. The slopes show a tendency to become steeper as the cooling time increases, again suggesting that at least body fat has an increasing significance to skin temperature with the passage of time in the cold.

The two University student populations were not submitted to regression analysis not only because of small sample size but also because there is no comparable material on larger populations.

Only in the Chinchero group is the sample size sufficiently large to provide reasonable regression slope estimates. The simple correlations and the multiple correlations suggest that the fat-free weight and the percent of body fat are the two most significant body characteristics in relationship to the temperature of the toe. Regressions for these two variables are presented in Table 5.

Table 5

Regressions for predicting toe temperature from fat-free weight and % body fat.

Chinchero Indians

Time	F.F.W. Regression in Kg.	% Body Fat Regression
0	Toe Temp. = .69x + 30.96° F.	Toe Temp. = -.82x + 72.43° F.
20	Toe Temp. = .61x + 33.74° F.	Toe Temp. = -.98x + 72.44° F.
40	Toe Temp. = .52x + 37.44° F.	Toe Temp. = -1.05x + 72.11° F.
60	Toe Temp. = .47x + 38.86° F.	Toe Temp. = -.83x + 69.24° F.
80	Toe Temp. = .39x + 42.81° F.	Toe Temp. = -.66x + 67.78° F.
100	Toe Temp. = .32x + 45.60° F.	Toe Temp. = -.46x + 65.44° F.
120	Toe Temp. = .26x + 48.14° F.	Toe Temp. = -.33x + 64.14° F.

The regression of fat-free weight to toe temperature is a positive one indicating that the larger the mass of the fat-free body, the higher the toe temperatures. The slope of the regression decreases through the cooling period indicating that with the passage of time in the cold, the fat-free weight gradually loses its significance to toe temperature. This does not mean however that there is no association remaining at the end of the cooling period. Indeed the correlation remains significant throughout. However, the toe temperature of the largest man shows a greater drop from initial to final readings than the toe temperature of the smaller man. The relationship between body fat and toe temperature is negative indicating that the larger the amount of body fat the lower the toe temperature. The slopes of the regression do not show a consistent trend during the cooling. Instead for the first forty minutes the slope of the regression increases, thereafter it decreases.

Regressions for hand temperature based on body weight and sitting height are presented in Table 6. These characteristics were chosen because of the correlation they bear to hand temperature and the importance shown by multiple correlation with parsimony.

Table 6

Time	Body Weight Regression in Kg.	Sitting Height in Cm.
0	Hand Temp. = .30x + 64.50° F	Hand Temp. = .68x + 29.70° F
20	Hand Temp. = .25x + 64.02	Hand Temp. = .41x + 44.70
40	Hand Temp. = .17x + 69.93	Hand Temp. = .37x + 45.69
60	Hand Temp. = .14x + 67.59	Hand Temp. = .39x + 43.03
80	Hand Temp. = .20x + 64.42	Hand Temp. = .46x + 37.39
100	Hand Temp. = .25x + 61.37	Hand Temp. = .35x + 46.19
120	Hand Temp. = .21x + 62.71	Hand Temp. = .38x + 42.84

The body weight and sitting height regressions to hand temperature are both positive, indicating greater body weight and higher sitting height are both associated with higher hand temperatures. In neither case does there appear to a consistent change in the slope of the regression during the cooling period.

Rectal temperature prediction is made on the basis of age and sum of skin folds. Table 7 presents these regressions. Age shows a negative regression slope to rectal temperature, i.e. the older the individual the lower the rectal temperature.

Table 7

Regressions for predicting rectal temperature from age and sum of skin folds.

Chinchero Indians

Time	Age in years	Sum of Skinfolds in Mm.
0	Rectal Temp. = -.0099x + 99.25° F	Rectal Temp. = .018x + 98.29° F
20	Rectal Temp. = -.013x + 99.26	Rectal Temp. = .020x + 98.13
40	Rectal Temp. = -.016x + 99.28	Rectal Temp. = .019x + 98.09
60	Rectal Temp. = -.018x + 99.14	Rectal Temp. = .021x + 97.82
80	Rectal Temp. = -.019x + 99.07	Rectal Temp. = .024x + 97.59
100	Rectal Temp. = -.020x + 99.10	Rectal Temp. = .026x + 97.35
120	Rectal Temp. = -.023x + 99.09	Rectal Temp. = .025x + 97.37

Sum of skin folds has a positive regression slope, showing the higher the sum of skin folds the higher the rectal temperature. Age shows a consistent trend over the cooling period with the slope of the regression becoming steeper as body heat is lost. This suggests that age has an increasingly important role in rectal temperature with the length of time the person is cooled. Despite some variation during the first three time periods of measurements there appears to be an overall rise in the steepness of the slope when relating skin folds to rectal temperature also suggesting that the importance of the fat thickness increases with the length of time of cooling.

In Table 8 mean weighted skin temperature prediction is shown on the basis of age. No other variable showed consistent significant correlation to mean weighted skin temperature. The association is negative indicating that the older the individual the lower the mean weighted skin temperature.

Table 8

Regression for predicting mean
weighted skin temperature from age

Chinchero Indians

Time	Age in years
0	M.W.S.T. = -.012x + 86.39
20	M.W.S.T. = -.020x + 85.95
40	M.W.S.T. = -.015x + 85.22
60	M.W.S.T. = -.011x + 84.71
80	M.W.S.T. = -.017x + 84.89
100	M.W.S.T. = -.025x + 85.01
120	M.W.S.T. = -.027x + 84.97

During the first hour of cooling no consistent change of the slope of the regression appears, but during the second hour of cooling the regression slope increases in its steepness, again suggesting that age has increasing importance in the mean weighted skin temperature with the extension of body cooling.

Discussion and Conclusions

The analysis of body characteristics in relation to temperature responses in the four groups of this study has shown that in high altitude cold exposure, body fat is significant to the rate of cooling, and as has been shown at lower altitudes for U. S. Whites it acts as insulation. Despite the smallness of the U. S. White sample the data also suggest that the mass of the fat-free body should be considered as a significant factor in the rate and degree of body cooling.

In the analysis, significant differences between the U. S. White and the Chinchero Indian groups were found. Age was the prime factor in the Indian groups in relation to overall indices of body cooling, while fat and fat-free weight were of prime importance for the Whites. Nevertheless, this should not be interpreted as necessarily signifying a functional difference between the populations. The age range in the U. S. White sample was much more limited than the age range in the Indian sample and the body fat range was much greater in the U. S. White sample than it was in the Indian group. It is therefore possible that the differences in the selection of prime predictors and in the significance of correlations was an artifact of sampling and not a real difference in the populations.

The careful matching of the two University of Cuzco student populations should make the data obtained from their study helpful in chosing between the alternatives of sampling and real group differences. The results of the student comparisons <u>suggest</u> that the White and Indian may not respond identically, and body characteristics may not have the same relationship to cooling responses in the two groups. However, firm conclusions do not seem warranted, because of the small sample sizes and the restricted range of age and fatness in these populations.

Within twenty minutes after the beginning of the cooling exposure the toe temperatures of the U. S. Whites reached almost ambient temperature and they remained at this level throughout the test period. The lack of variability within the group made any significant correlation between toe temperatures and body characteristics impossible. Toe temperatures for the student groups are also low, though not as low as

the U. S. Whites. Only the Chinchero Indian group maintained toe temperatures substantially above ambient temperatures. As shown by regression analysis, the maintenance of toe temperature was not universal for the Chinchero individuals. The small, thin Chinchero man had a toe temperature as low as the U. S. Whites and only the heavier and fatter individuals maintained elevated reading.

These results support the suggestion that the Chinchero Indians have a higher metabolic response to cold exposure. Since fat free weight is the prime factor in prediction it might be deduced that the greater mass of metabolically active tissue produces more heat and this is reflected in greater heat flow to the extremities.

The results of the hand temperature analysis can be interpreted as supporting this suggestion. However, the group differences are not so clearly defined, perhaps because more arm movement than leg movement was permitted during the test.

The overall body temperature measurements of rectal and mean weighted skin temperature also suggest such an interpretation since the negative relationships between age and these measures may reflect the declining ability of the body with age to support maximal heat production.

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APPENDIX A

BIVARIATE CORRELATIONS BETWEEN BODY CHARACTERISTICS AND BODY TEMPERATURE

At Initial Exposure to 14° C

U.S. Whites N=5

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.408	-.119	.837	-.658
St.H	-.976**	-.506	.490	.534
Si.H	.773	-.176	.459	-.597
BW	.228	.321	.794	-.656
%BF	.304	-.170	.750	-.880*
FFW	.192	.459	.755	-.541
SSF	.110	-.268	.486	-.792

Cuzco Whites N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.200	.294	.208	.004
St.H	.281	.277	-.107	-.421
Si.H	.045	.040	.428	-.271
BW	.540	.293	-.275	-.323
%BF	.307	.044	.299	-.217
FFW	.542	.316	-.377	-.315
SSF	.276	.051	.334	-.230

Cuzco Indians N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.422	.387	-.386	.124
St.H	-.200	-.228	-.184	-.309
Si.H	-.362	-.633*	-.081	-.542
BW	.048	.017	.022	-.189
%BF	.276	.374	-.007	-.139
FFW	-.018	-.081	.027	-.132
SSF	.256	.296	.041	-.164

Chinchero Indians N=24

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.269	-.187	-.365	-.172
St.H	.422*	.416*	-.220	.281
Si.H	.343	.514**	-.004	.356
BW	.502*	.396	.003	.302
%BF	-.150	-.187	.334	-.034
FFW	.534**	.430*	-.043	.320
SSF	-.242	-.156	.364	-.080

St.H=Standing Height, Si.H=Sitting Height, BW=Body Weight, %BF=Percent Body Fat, FFW=Fat Free Weight, SSF=Sum of Skin Fold.

* = $p < .05$
** = $p < .01$

After 20 Minutes at 14° C

U.S. Whites N=5

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.642	.234	.809	-.707
St.H	-.238	-.837	-.413	.073
Si.H	.886*	.290	.360	-.435
BW	-.283	.583	.839	-.606
%BF	.199	.312	.758	-.937*
FFW	-.420	.634	.809	-.457
SSF	-.043	.154	.514	-.893*

Cuzco Whites N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.414	.050	.184	-.130
St.H	.071	.223	-.214	-.385
Si.H	-.140	-.065	.358	-.234
BW	.428	.393	-.340	-.171
%BF	.218	.266	.233	-.184
FFW	.436	.382	-.437	-.152
SSF	.162	.282	.283	-.172

Cuzco Indians N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.453	.221	-.194	.080
St.H	-.100	-.274	-.097	-.321
Si.H	-.321	-.505	-.021	-.529
BW	.192	.153	.142	-.110
%BF	.324	.467	.028	-.061
FFW	.129	.050	.151	-.112
SSF	.297	.436	.078	-.063

Chinchero Indians N=24

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.231	-.112	-.469*	-.314
St.H	.376	.229	-.059	.222
Si.H	.342	.342	.137	.285
BW	.492*	.318	.131	.157
%BF	-.203	-.140	.376	-.100
FFW	.532**	.342	.080	.177
SSF	-.284	-.113	.413*	-.088

St. H=Standing Height, Si.H=Sitting Height, BW=Body Weight, %BF=Percent Body Fat, FFW=Fat Free Weight, SSF=Sum of Skin Folds.

* = $p < .05$
** = $p < .01$

After 40 minutes at 14° C

U.S. Whites N=5

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	-.206	.197	.862	-.588
St.H.	-.517	-.418	-.359	-.107
Si.H	.475	-.116	.396	-.395
BW	-.159	.758	.794	-.522
%BF	.126	.342	.753	-.876
FFW	-.236	.842	.754	-.372
SSF	.225	.249	.488	-.895*

Cuzco Whites N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.390	-.034	.192	-.220
St.H	.166	.099	-.125	-.384
Si.H	-.131	-.120	.387	-.217
BW	.558	.340	-.210	-.223
%BF	.320	.285	.322	-.224
FFW	.561	.319	-.309	-.203
SSF	.258	.304	.367	-.198

Cuzco Indians N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.255	.295	-.245	.070
St.H	-.285	-.232	-.163	-.319
Si.H	-.404	-.596*	-.148	-.506
BW	-.034	.120	.125	-.283
%BF	.247	.382	.220	-.293
FFW	-.107	.032	.085	-.247
SSF	.251	.315	.266	-.294

Chinchero Indians N=24

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.242	-.226	-.524**	-.288
St.H	.274	.169	.161	.027
Si.H	.282	.337	.332	.085
BW	.451*	.262	.242	-.016
%BF	-.237	-.180	.298	-.062
FFW	.495**	.295	.202	-.003
SSF	-.272	-.123	.348	-.078

St.H=Standing Height, Si.H=Sitting Height, BW=Body Weight, %BF=Percent Body Fat, FFW=Fat Free Weight, SSF=Sum of Skin Folds.

* = $p < .05$
** = $p < .01$

After 60 Minutes at 14° C

U.S. Whites N=5

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	-.337	.425	.777	-.587
St.H.	-.079	.390	-.531	-.149
Si.H.	.147	-.290	.414	-.257
BW	-.291	.615	.830	-.550
%BF	.016	.779	.747	-.883*
FFW	-.368	.769	.002	-.404
SSF	.244	.824	.508	-.995*

Cuzco Whites N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.174	.023	.254	-.256
St.H.	.117	.202	-.160	-.482
Si.H.	-.032	-.115	.288	-.183
BW	.556	.500	-.167	-.250
%BF	.400	.630*	.359	-.195
FFW	.527	.425	-.269	-.240
SSF	.395	.613*	.405	-.151

Cuzco Indians N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.393	.248	-.142	.146
St.H	-.088	-.175	-.099	-.355
Si.H	-.229	-.513	-.014	-.534
BW	.082	.116	.194	-.325
%BF	.166	.362	.155	-.342
FFW	.044	.025	.179	-.285
SSF	.165	.328	.200	-.345

Chinchero Indians N=24

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.223	-.305	-.577**	-.214
St.H	.346	.136	.190	.156
Si.H.	.369	.353	.349	.227
BW	.502*	.216	.256	.008
%BF	-.226	-.147	.313	-.139
FFW	.545**	.235	.211	.031
SSF	-.285	-.061	.381	-.183

St.H = Standing Height, Si.H = Sitting Height, BW = Weight, %BF = Percent Fat, FFW = Fat Free Weight, SSF - Sum of Skin Folds

* = p. .05
** = p. .01

After 50 Minutes at 14° C

U. S. Whites N=5

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	-.032	.002	.747	-.528
St.H.	-.409	-.330	-.598	.235
Si.H.	.562	-.229	.447	-.475
BW	-.299	.660	.838	-.500
% BW	.088	.165	.777	-.844
FFW	-.401	.776	.803	-.356
SSF	.157	.122	.561	-.857

Cuzco Whites N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.372	.106	.017	-.032
St.H.	.015	-.084	-.112	-.526
Si.H.	-.202	-.320	.162	-.263
BW	.635*	.350	-.101	-.104
%BF	.528	.578*	.347	-.015
FFW	.602*	.264	-.191	-.116
SSF	.498	.599*	.396	.009

Cuzco Indians N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.312	.482	-.161	.228
St.H.	.184	-.006	-.069	-.308
Si.H.	.146	-.458	.016	-.545
BW	.311	.121	.255	-.188
% BF	.165	.255	.221	-.201
FFW	.292	.067	.233	-.166
SSF	.169	.166	.278	-.223

Chinchero Indians N=24

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.194	-.279	-.588**	-.299
St.H.	.236	.243	.226	.137
Si.H.	.211	.420*	.375	.275
BW	.434*	.304	.287	.107
%BF	-.171	-.274	.348	-.043
FFW	.472*	.330	.236	.120
SSF	-.197	-.134	.418*	-.067

St.H = Standing Height, Si.H. = Sitting Height, BW = Weight, %BF = Percent Fat, FFW = Fat Free Weight, SSF = Sum of Skin Folds.

* = p. .05
** = p. .01

After 100 Minutes at 14° C.

U.S. Whites N=5

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	-.393	.020	.665	-.588
St.H.	.246	-.420	-.465	.185
Si.H.	.081	-.247	.253	-.479
BW	-.633	.620	.936*	-.518
%BF	-.258	.134	.814	-.873
FFW	-.721	.736	.913*	-.369
SSF	-.054	.066	.659	-.868

Cuzco White N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.262	-.193	.008	-.287
St.H.	.104	-.068	.003	-.394
Si.H.	-.227	-.452	.217	-.193
BW	.644*	.113	.071	-.207
%BF	.608*	.295	.472	-.132
FFW	.593*	.063	-.025	-.207
SSF	.599*	.269	.525	-.096

Cuzco Indians N=12

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.274	-.010	-.103	-.043
St.H.	-.148	-.366	-.060	-.342
Si.H.	-.073	-.501	.008	-.414
BW	.019	.063	.304	-.241
%BF	.018	.460	.242	-.244
FFW	.011	-.053	.282	-.223
SSF	.057	.419	.292	-.224

Chinchero Indians N=24

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
Age	.295	-.242	-.582**	-.429*
St.H	.294	.241	.233	.137
Si.H	.363	.352	.380	.249
BW	.480*	.383	.322	.044
%BF	-.178	-.021	.352	-.082
FFW	.520**	.384	.272	.060
SSF	-.233	.075	.414*	-.092

St.H. = Standing Height, Si. H. = Sitting Height, BW = Weight, % BF = Percent Fat, FFW = Fat Free Weight, SSF = Sum of Skin Folds

* = p. .05
** = p. .01

After 120 Minutes at 14° C.

	Toe Temperature	Hand Temperature	Rectal Temperature	Mean Weighted Skin Temperature
U.S. Whites N=5				
Age	-.228	.181	.666	-.297
St.H.	-.423	-.535	-.425	.341
Si.H.	.159	.030	.234	-.349
BW	.131	.397	.952*	-.499
% BF	.259	-.014	.843	-.743
FFW	.085	.505	.923*	-.388
SSF	.154	-.219	.701	-.829
Cuzco White N=12				
Age	.370	-.020	-.135	-.087
St. H.	.099	.152	.121	-.402
Si. H.	-.179	.141	.106	-.025
BW	.692*	.393	.204	-.177
% BF	.639*	.444	.503	-.156
FFW	.642*	.341	.119	-.168
SSF	.611*	.474	.554	-.119
Cuzco Indian N=12				
Age	.787**	-.071	-.096	-.179
St.H.	.314	-.334	-.229	-.463
Si.H.	.010	-.431	-.143	-.540
BW	.208	.092	.197	-.373
% BF	-.079	.344	.216	-.216
FFW	.249	.008	.167	-.369
SSF	-.129	.335	.257	-.201
Chinchero Indian N=24				
Age	.307	-.243	-.612**	-.414*
St. H.	.299	.273	.177	.181
Si. H.	.383	.379	.348	.272
BW	.460*	.345	.270	.055
% BF	-.166	-.129	.290	-.010
FFW	.518**	.359	.224	.057
SSF	-.224	-.051	.372	.002

St. H. = Standing Height, Si. H. = Sitting Height, Bw = Weight, % BF = Percent Fat, FFW = Fat Free Weight, SSF = Sum of Skin Folds.

* = p. .05
** = p. .01

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